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Tactical Decision Aid Sensitivity to Data Resolution

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Louis A. Hembree, Jr.
Naval Systems Support Branch
Atmospheric Directorate
Monterey, CA 93943-5006

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Stennis Space Center, Mississippi 39529-5004.

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ABSTRACT

Tactical Decision Aids (TDAs) described in the Geophysical Fleet Mission Program Library and the Tactical Environmental Support System 2.0 were reviewed. Subjective assessments as to the TDAs' sensitivity to data resolution were made. Spatial (horizontal and vertical) and time resolution were considered. Those TDAs with the highest apparent sensitivity were identified. Recommendations are made as to the order in which further sensitivity studies should be conducted. Sensors presently available to measure increased spatial and time resolutions are also discussed.

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TACTICAL DECISION AID SENSITIVITY TO DATA RESOLUTION

1.0 INTRODUCTION

This report addresses the sensitivity of various Tactical Decision Aids (TDAs) to data resolution in time and space. The technology to acquire higher resolution data within the fleet for decision making and input to TDAs and weapon systems is available. However, before time and effort are committed to the development of operational equipment to provide the data and programs to use the data, some analysis is required to determine if the new data would be of value.

The TDAs reviewed are limited to those contained in the Geophysical Fleet Mission Program Library (GF MPL) and the Tactical Environmental Support System (TESS) 2.0 libraries that utilize meteorological profile information. Table 1 is a listing of these TDAs as well as a brief description of each TDA and the environmental parameters required.

2.0 SENSITIVITY ANALYSIS

A detailed sensitivity analysis of each of these TDAs is beyond the scope of the current project. The detailed sensitivity analysis of a single TDA could take several man-months. Instead, the GF MPL and TESS 2.0 technical specifications and documentation of each TDA were used. The information in these documents was reviewed and subjective judgments of the sensitivity were made. It is believed that this would be of value in determining the need of increased data resolution and to help prioritize the TDAs that should be examined in more detail. Each TDA is discussed briefly below. A complete description of each TDA is not included but may be found in Support System Baseline (TESS 2.0) Program Performance Specification.

Table 1. List of TDAs reviewed. (*Refractivity calculated from temperature and humidity.)

<u>NAME</u>	<u>FUNCTION</u>	<u>ENVIRONMENTAL INPUT VARIABLES</u>	<u>OUTPUT</u>	<u>FORM</u>
AIRICE	Aircraft ice accumulation	Temperature Humidity Geopotential	Icing types intensity probabilities	Tables
METBAL	Computes ballistic wind and density correction factors for Naval gunfire support.	Wind Profile Density	Correction factors	Tables
RADFO	Provides the capability to determine the best maneuvering action for a ship/unit to minimize the effects of radiological fallout.	Wind profile	Dosage and deposition	Tables Graphics
CHAPP	Computes chaff displacement	Wind profile	Displacement height	Table Graphic
SOCUS	Sound focus. Determines whether atmospheric conditions favor the formation of caustics (sound focus points) or large scale refraction of sound.	Temperature Wind profile	Sound speed, max sound pressure location	Table Graphic
COVER	Display detection or communication coverage in the vertical plane	Temperature Humidity Refractivity* Surface Wind Evap. Duct Ht	Coverage diagram	Graphic
LOSS	EM path loss versus range Allows determination of maximum detection, intercept, and communication ranges	Temperature Humidity Surface wind Refractivity* Evap. Duct Ht	Loss diagram	Graphic
ESM	Computes maximum intercept of surface-based ESM receivers	Temperature Humidity Refractivity* Surface Wind Evap. Duct Ht	Ranges	Table
SSR	Computes detection ranges for surface search radars, SPS-10 AND SPS-55	Temperature Humidity Surface wind Evap. Duct Ht Refractivity*	Ranges	Table

Table 1, continued.

ENVIRONMENTAL				
<u>NAME</u>	<u>FUNCTION</u>	<u>INPUT VARIABLES</u>	<u>OUTPUT</u>	<u>FORM</u>
ECM	Determine effectiveness of a jamming system	Temperature Humidity Surface Wind Evap. Duct Ht Refractivity*	Effectiveness	Table Graphic
FLIR	Computes detection ranges against surface targets	Temperature Humidity Pressure Wind speed Visibility	Detection ranges	Table
EMPCS	EM propagation condition summary. Provides capability to determine salient characteristics of EM propagation. (SPS48 default)	Temperature Humidity Surface Wind Evap. Duct Ht Refractivity*	Summary, height range for extended ranges and holes	Table Graphic
IREPS	Provides for evaluation of refractive effects. Loss, relative ranges, coverage	Temperature Humidity Surface wind Evap. Duct Ht Refractivity*	Coverage and loss diagram, ranges	Table Graphic
PV	Estimates vulnerability of various platform emitters to specified ESM	Temperature Humidity Surface wind Evap. Duct Ht Refractivity*		Graphic Table
BGV	Estimates vulnerability of BG platforms	Temperature Humidity Surface wind Evap. Duct Ht Refractivity*		Graphic Table

2.1 AIRICE

The AIRICE TDA is used to estimate aircraft ice accumulation. The algorithm uses radiosonde temperature and humidity data to produce tables of icing types, intensity, and probabili-

ties. In general, algorithms used to predict or estimate aircraft icing have fairly large error bounds. They therefore tend to err in favor of safety and predict icing more frequently than actually occurs. A national committee is now working on new aircraft icing prediction algorithms. As these new algorithms become available they should be examined to see if they should replace the current algorithm used.

Radiosondes are the current source of profiles for input to the icing algorithm. The vertical resolution of the radiosonde data is probably adequate for defining the icing layers when the significant levels are used. However, during ascent, radiosondes can drift large distances. The measurements are assumed to apply at the radiosonde site. The horizontal homogeneity of icing conditions is low and the drift of the radiosonde is a source of error in the estimation of icing probabilities. The time continuity of icing is also a variable. Therefore, in order to detect changes in icing, profiles should be available at more frequent time intervals.

A problem associated with the radiosonde is that it is too costly to launch frequently. Any other instrument used to measure temperature and humidity profiles for use in this algorithm would have to be able to penetrate clouds. This rules out the use of lidar profilers. However radiometers may be able to provide such measurements. In addition, radiometers could also provide an estimate of the liquid water content of the clouds, which is an important parameters in estimating icing. The high resolution IR interferometer sounder, HIS, is a recently de-

veloped instrument that may also be able to provide such measurements. The vertical resolution of this instrument when used in a surface based mode is now under evaluation by researchers at the NOAA Wave Propagation Laboratory.

2.2 METBAL

The METBAL TDA is used to compute ballistic wind and density correction factors for Naval gunfire support to ensure close hits with initial firings. The correction factors are used to correct for deviations from a calm standard atmosphere. The methodology is closely tied to the NATO method. Ideally the corrections should be applied at every point along the trajectory. However, to simplify calculation, by NATO agreement the atmosphere has been divided into 15 zones (see Table 2).

The data required are wind, temperature, humidity, and geopotential height information from a nearby radiosonde. The radiosonde data is converted to density which is averaged over the zones. Radiosonde winds typically represent winds averaged over a two minute interval which corresponds to an approximate height interval of 600 meters. The temperature and humidity data typically have a resolution of 90 m or better. Improving the vertical resolution of the data would provide better estimates of the averages, however, with the current resolution of the METBAL algorithm, it is likely that little overall improvement would be realized. The most obvious candidate for improvement would be wind measurement below 2000 m. Resolution better than 200 m would be desirable.

Table 2. NATO standard levels for ballistic wind corrections.

Code	ZONE	STANDARD VALUES	
	Heights of Limits m above SFC	Virtual Temperature K	Density Kg/m ³
00	Surface	288.150	1.2250
01	0 - 200	287.500	1.2133
02	200 - 500	285.875	1.1844
03	500 - 1,000	283.275	1.1392
04	1,000 - 1,500	280.025	1.0846
05	1,500 - 2,000	276.775	1.0320
06	2,000 - 3,000	271.900	.9569
07	3,000 - 4,000	265.400	.8632
08	4,000 - 5,000	258.900	.7768
09	5,000 - 6,000	252.400	.6971
10	6,000 - 8,000	242.650	.5895
11	8,000 - 10,000	229.650	.4664
12	10,000 - 12,000	218.275	.3612
13	12,000 - 14,000	216.650	.2655
14	14,000 - 16,000	216.650	.1937
15	16,000 - 18,000	216.650	.1413

Lidar profilers would be able to provide measurements of temperature, humidity, and winds with a vertical resolution of at least 300 m to an approximate height of 10 km. The lowest level would be between 300 and 500 m. Coverage below this level and improved resolution at the lower levels could be provided by including a scanning capability on a Doppler lidar profiler. This could not be done with a lidar using a correlation approach to determine the winds. (The correlation methods uses the correlation between two vertically pointing beams to define the time it takes a feature to move between the beams, and from this the velocity is calculated.) A shortcoming of the lidar as mentioned above is its inability to penetrate clouds or fog. Another in-

strument that could provide wind profiles is a Doppler radar wind profiler. It has resolutions comparable to those of the lidar. It can operate in fog and clouds. It can also operate in precipitation, however the maximum precipitation rate is a function of the wavelength.

2.3 RADFO

The RADFO TDA provides the capability to determine the best maneuvering action for a ship/unit to take to minimize the effects of radiological fallout. Besides information on the nature and location of the blast, the TDA requires wind data from a specified radiosonde. The TDA does not consider the influence of additional meteorological parameters such as turbulence, clouds, precipitation, and vertical air movements. The first model layer extends from the surface to 100 m, the second from 100 m to 500 m, and the remaining layers are 1 km thick to 31,500 m (see Figure 1). The winds are interpolated to the mid points of each layer. Other than near the surface, increasing the vertical resolution of the data would not result in better estimates from the TDA as it does not now utilize the available resolution from standard radiosondes. The upper height requirement of 31,500 m, currently eliminates surface based lidar wind profilers as this is beyond their present range capability. Doppler radar wind profilers that can reach this altitude are too large for operational ship installation. However, if the source of improved data is to be ship based, there is another consideration. That is, how often would a profile at the ship's location be the close to the blast location which could be some distance from the

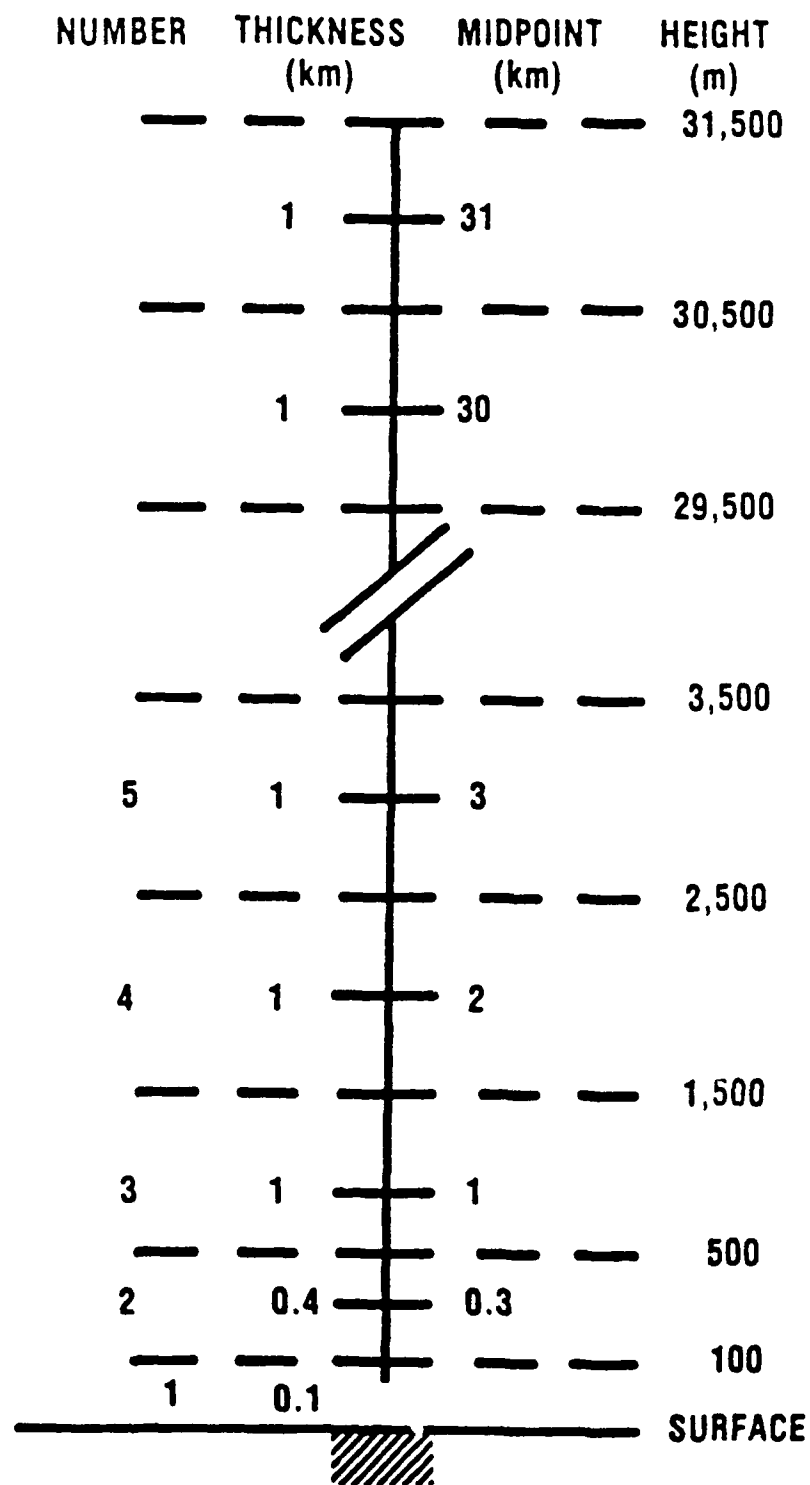


Figure 1. RADFO Layers and Levels. (The layer midpoint height, the layer thickness, and the identification number are shown.)

ship, in which case a ship based profile may be of little value. This argues for an improved satellite wind sounding capability.

2.4 CHAPP

The CHAPP TDA is used to compute chaff displacement and dispersion. The TDA requires a wind profile. The TDA uses wind data from a specified radiosonde. The current implementation performs the calculations for 1 km thick layers. Increasing the vertical resolution of the data would result in smoother estimates from the TDA. However, a net improvement in usefulness may not be observed due to other uncertainties in the wind field such as the horizontal variability. As with several of the TDAs, if the source of improved data is to be ship based, there is another consideration. That is, how often would a profile at the ships location be the correct profile to be used? The correct profile to use should be close to the release location which could be some distance from the ship, in which case a ship based profile may be of little value. This argues for an improved satellite wind sounding capability.

2.5 SOCUS

The sound focus (SOCUS) TDA is used to assist in determining if atmospheric conditions favor the formation of caustics or large scale refraction of sound in the vicinity of populated areas. The TDA requires vertical profiles of temperature, wind speed, and wind direction at the significant levels. These are used to calculate profiles of sound speed. Whether or not higher resolution temperature data would result in a significant im-

provement is unknown. However, it is believed that improved resolution in the winds would be useful as the radiosonde winds are two minute averages, corresponding to about 600 meters. Wind profiles measured using a lidar profiler or wind profile would be significantly better than this.

2.6 COVER

The COVER TDA is used to determine and display the detection or communication coverage in the vertical plane. The primary data source is refractivity profile information calculated using temperature and humidity from radiosonde soundings. Higher resolution profiles would modify the number and strength of ducts in the profiles, which in turn would modify the coverage diagrams. Of equal or more importance would be an increase in the frequency of the soundings. Refractivity profiles can vary significantly over a twelve hour period, and the ability to monitor these changes could be critical. Also of importance is the horizontal variation of the refractivity, particularly near the sea surface, since some radars have large operational ranges. The sounding used is either one located at a nearby shore station or the one taken on the battle group carrier. As a result the sounding may be displaced significantly from the point of application leading to errors due to horizontal variability. Even though the current TDA algorithms cannot incorporate horizontal variation, work is proceeding on methods that could. Successful implementation of the new methods would require information on the horizontal variation of the refractivity. This is not currently available.

An instrument that could be deployed on several of the combatants within a battle group would help define this variation.

A lidar profiler would be able to provide the required profiles of temperature and humidity. Current DIAL lidars have resolutions between 150 and 300 m which is too coarse for this application. Raman lidars have sufficient resolution, however their maximum range (altitude) is limited to between one and two kilometers. A scanning lidar would be able to provide much better vertical resolution near the surface and also be able to monitor the evaporation duct. When looking near the horizontal, the vertical resolution is determined by the beam width, in this case a fraction of a degree. The HIS instrument previously mentioned could also provide the required profiles. However, its resolution is still being determined.

2.7 LOSS

The LOSS TDA allows the estimation of maximum detection, intercept, and communication ranges. It requires the refractivity profile and surface wind at the location of interest. The comments concerning data effects on the COVER TDA also apply for this TDA.

2.8 ESM

The ESM TDA computes the maximum intercept range of surface-based ESM receivers. It uses a refractivity profile to and produces a table of ranges of selected receivers and threat transmitters. The comments concerning data effects on the COVER TDA also apply for this TDA.

2.9 ECM

The electronic counter measures (ECM) TDA is used to estimate the effectiveness of a specified jamming system. It requires the refractivity profile and surface wind at the location of interest. The comments concerning data effects on the COVER TDA also apply for this TDA.

2.10 SSR

The SSR TDA is used to compute detection ranges for surface search radars. Its data requirements include a refractivity profile, surface wind, and the evaporation duct height. The comments concerning data effects on the COVER TDA also apply for this TDA.

2.11 EMPCS

The Electromagnetic Propagation Conditions Summary (EMPCS) TDA is used to determine the salient characteristics of electromagnetic propagation for the specified atmospheric conditions. A graphic showing the M-unit profile and the locations of ducts is produced along with a narrative description. The narrative states what type of ranges should be expected and the possibility of holes in the coverage. The TDA requires a refractivity profile and the evaporation duct height. The comments for the COVER TDA apply.

2.12 PV

The platform vulnerability (PV) TDA is used to determine the maximum range at which a specified threat receiver would be able

to detect active emitters on the platform. The TDA requires a refractivity profile and the evaporation duct height. The comments made for the COVER TDA apply.

2.13 BGV

The battle group vulnerability (BGV) TDA is similar to the PV TDA, however it is a composite of the vulnerabilities of the platforms comprising the battle group. The TDA requires a refractivity profile and the evaporation duct height. The comments made for the COVER TDA apply. In addition, it should be noted that the same profile and evaporation duct height is used for all platforms in the battle group. This assumption may not always be valid as significant differences in one or both could occur across a battle group. If an instrument was available that could be deployed on several of the platforms a better picture of the refractive conditions could be obtained.

2.14 FLIR

The Forward-Looking Infrared (FLIR) TDA is used to compute detection ranges for surface targets. It requires profilest of temperature, humidity, pressure, and surface wind speed and visibility as input. Depending on the path length and geometry, the FLIR prediction would be improved with high resolution data. However, often the prediction is made for a location remote from the platform, therefore high resolution data obtained at the platform may be of little or no value. Satellites may be a means to address this problem. Methods are currently being developed to retrieve visibility and/or aerosol information using satel-

lites. This would help resolve the problem of making predictions at other locations.

3.0 SUMMARY

Table 3 is a summary of the review results. All of the TDAs would benefit from more frequent data. More frequent data would allow significant changes in conditions to be more closely monitored. As far as spatial resolution, three would seem to benefit little from inclusion of higher resolution data. These TDAs are AIRICE, RADFO, and CHAPP. In general the current data resolution appears to be sufficient for the algorithms used. In addition, RADFO and CHAPP are likely to be applied at locations where the high resolution data would not be available. This last point also applies to the FLIR TDA. While the FLIR TDA could very likely benefit from higher resolution data, the point of application may preclude its availability. The SOCUS and METBAL TDAs could both conceivably benefit from improved data resolution. SOCUS could benefit from higher resolution wind profiles, however sensitivity studies using simulations would need to be conducted to confirm this. While METBAL could possibly be improved with higher resolution data, especially at lower levels, the algorithms would need to be modified and a detailed sensitivity analysis performed to determine if a significant improvement could be obtained.

All of the TDAs dealing with some aspect of electromagnetic propagation would benefit from increased data resolution in time as well as the vertical and horizontal. The higher resolution data would allow the better evaluation of the environmental

Table 3. Summary of results of subjective review of TDAs for sensitivity to data resolution.

TDA	VERTICAL	HORIZONTAL	TIME ⁺
AIRICE	Low	Moderate	Moderate
RADFO	Low	None*	Moderate
METBAL	Low [@]	None*	Moderate
CHAPP	Low	None*	Moderate
SOCUS	Low [@]	None*	Moderate
FLIR	High	High	High
COVER	High	High [#]	High
LOSS	High	High [#]	High
ESM	High	High [#]	High
SSR	High	High [#]	High
ECM	High	High [#]	High
EMPCS	High	High [#]	High
IREPS	High	High [#]	High
PV	High	High [#]	High
BGV	High	High [#]	High

⁺ Increase in time resolution accomplished by rerunning model with new data.

* Current algorithm cannot incorporate data from more than one site; this would require extensive model redevelopment.

[@] Might have moderate sensitivity

[#] Current algorithms do not incorporate horizontal inhomogeneity, however methods are being developed.

effects on propagation. Higher vertical resolution would require little if any program modification. Multiple soundings in the horizontal will be required when algorithms incorporating horizontal inhomogeneity are completed.

It is recommended that a program of testing TDA data sensitivity be initiated. This program would examine the sensitivity of each TDA to data resolution, the assumptions made in the TDA, and modifications required to make optimum use of high resolution data. Using a simulation approach, different sensors could be evaluated as data sources. The TDAs concerning EM propagation should be the first to be studied as they are probably the most

frequently used and would probably show the most improvement in the short term with improved data. Both time and spatial (vertical and horizontal) resolution need to be addressed when studying the EM TDAs. The FLIR TDA should be the next one studied. It is also sensitive to time and spatial variability. The study needs to be done to help set limits on the required satellite resolution. The METBAL and SOCUS TDAs should be next ones to be examined with primary emphasis placed on the sensitivity to vertical resolution and time variation. The remainder of TDAs should then be studied. The AIRICE TDA could be moved up in priority if a means to monitor icing conditions from satellite appears likely.

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4301 SUTTLAND RD.
WASHINGTON, DC 20395-5180

NAVAIRSYSCOM
ATTN: CODE 526W
WASHINGTON, DC 20361-0001

SPAWARSYSCOM
ATTN: CODE PMW-141
NAT. CTR. #1
WASHINGTON, DC 20363-5100

SPAWARSYSCOM
ATTN: T. CZUBA, PMW141-10
WASHINGTON, DC 20363-5100

CHIEF OF NAVAL RESEARCH
ATTN: CODE 01232L
800 QUINCY ST.
ARLINGTON, VA 22217-5000

NAVWESTOCEANCEN
ATTN: OPERATIONS OFFICER
BOX 113
PEARL HARBOR, HI 96860

U.S. NAVOCEANCOMCEN
ATTN: OPERATIONS OFFICER
BOX 12, COMNAV MARIANAS
FPO SAN FRANCISCO 916630-2926

SPAWARSYSCOM
ATTN: CODE 312
NAT. CTR. #1
WASHINGTON, DC 20363-5100

NAVOCEANSYSCEN
ATTN: J. RICHTER, CODE 54
SAN DIEGO, CA 92152-5000

NAVAIRDEVCEEN
ATTN: K. PETRI
WARMINSTER, PA 18974

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